[0011] The present invention advantageously provides tactile feedback sensations for a tactile feedback device using electroactive polymer actuators. These actuators have several advantages, including high energy density, rapid response time, customizability in shape and performance characteristics, compactness, easy controllability, low power consumption, high force output and deflections/amount of motion, natural stiffness, sensing and actuation functions, relatively low raw materials cost, and relatively inexpensive manufacturing cost, making them desirable for haptic feedback and sensing devices.

[0012] These and other advantages of the present invention will become apparent to those skilled in the art upon a reading of the following specification of the invention and a study of the several figures of the drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** is a block diagram illustrating a haptic feedback system suitable for use with the present invention;

[0014] **FIG. 2***a* is a side elevational view of an electroactive polymer element in a bending motion;

[0015] **FIG. 2***b* is a top plan view of an electroactive polymer element in a bending motion;

[0016] **FIG. 2***c* is a side elevational view of an electroactive polymer sandwich structure providing linear and bending motion;

[0017] **FIG. 2***d* is a perspective view of an electroactive polymer element in a cylindrical configuration to provide motion in multiple degrees of freedom;

[0018] **FIG. 2***e* is a perspective view of an electroactive polymer structure that provides an area expansion of the element;

[0019] **FIG. 2***f* is a perspective view of an electroactive polymer structure in a cylindrical structure that provides axial motion of the element;

[0020] **FIG. 3** is a perspective view of an example mouse interface device suitable for use with EAP actuators of the present invention;

[0021] **FIG. 3***a* is a side elevational view of a mouse embodiment in which a button is moved in its degree of freedom by an electroactive polymer actuator;

[0022] **FIG. 3***b* is a top plan view of a mouse embodiment in which a button is moved laterally by an electroactive polymer actuator;

[0023] **FIG. 3***c* is a top plan view of a mouse embodiment in which a button includes an array of multiple electroactive polymer actuators;

[0024] **FIG. 4***a* is a schematic view of an embodiment in which an inertial mass is moved linearly by an electroactive polymer actuator to provide inertial sensations;

[0025] **FIG. 4***b* is a schematic view of an embodiment in which an inertial mass is moved rotationally by an electroactive polymer actuator to provide inertial sensations;

[0026] **FIG. 4***c* is a view of an embodiment in which multiple inertial masses are moved by an electroactive polymer actuators;

[0027] **FIG. 5***a* is a side view of a mouse embodiment in which a entire cover portion of the mouse is moved by an electroactive polymer actuator to provide tactile sensations;

[0028] **FIG. 5***b* is a top plan view of a mouse embodiment in which side portions of the mouse are moved by an electroactive polymer actuator to provide tactile sensations;

[0029] **FIG. 5***c* is a top plan view of a mouse embodiment in which top portions of the mouse are moved by an electroactive polymer actuator to provide tactile sensations;

[0030] **FIG. 5***d* is a side view of a mouse embodiment in which a rear top portion of the mouse is moved by an electroactive polymer actuator to provide tactile sensations;

[0031] **FIG. 6** is a top view of an embodiment in which a sphere is braked by an electroactive polymer actuator;

[0032] **FIG. 7***a* is a side view of a wheel embodiment in which a rotatable wheel includes an inertial mass that is rotationally moved by an electroactive polymer actuator;

[0033] **FIGS. 7***b* and **7***c* illustrate a wheel embodiment including a number of electroactive polymer actuators which expand in area;

[0034] **FIG. 7***d* is a perspective view of a wheel embodiment in which a rotatable wheel is braked by an electroactive polymer actuator;

[0035] **FIG. 7***e* is a side elevational view of a wheel embodiment in which the entire rotatable wheel is moved laterally and vertically by electroactive polymer actuators;

[0036] **FIG. 8***a* is a perspective view of a trackpoint controller in which an electroactive polymer actuator provides haptic feedback in its degrees of freedom;

[0037] **FIGS. 8***b* and **8***c* is perspective and side sectional views of a trackpoint controller in which an electroactive polymer actuator provides haptic feedback by linearly moving a poker against the user;

[0038] **FIG. 8***d* is a perspective view of a trackpoint controller in which electroactive polymer actuators provide haptic feedback in linear degrees of freedom;

[0039] **FIG. 9***a* is a perspective view of a vertical pin moved linearly by an electroactive polymer actuator against a user's finger;

[0040] **FIGS. 9***b* and **9***c* are perspective views of arrays of the vertical pins of **FIG. 9***a;*

[0041] **FIGS. 9***d* and **9***e* are side views of a vertical pin moved laterally by an electroactive polymer actuator against a user's finger;

[0042] **FIG. 10** is a side elevational view of a device in which an electroactive polymer actuator provides braking forces on a medical tool;

[0043] **FIG. 11** is a side elevational view of a device in which an electroactive polymer actuator provides forces to a trigger on an interface device;

[0044] **FIG. 12***a* is a front view of a knob in which an electroactive polymer actuator provides direct rotary forces in the rotary degree of freedom of the knob;